SPECIFICATION

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MOLTEN HYDRIDE FUEL CELL

Background of Invention

[0001] The present invention relates generally to the field of fuel cells, and more specifically to fuel cells comprising liquid electrolytes.

[0002] Various types of fuel cells are known in the art as devices that convert energy from a chemical reaction into electrical energy. Each type of fuel cell has one or more limitations that currently restrict its use to specialized applications. For example, thermally regenerative liquid fuel cells induce hydrogen flow by thermal decomposition of a mixture of lithium hydride and sodium hydride, at a high temperature (for example from about 800 ^{0} C to about 1300 ^{0} C) maintained by a separate heating device to generate hydrogen. The hydrogen is then passed through the cell at a high pressure (10 atmosphere or above) to mobilize hydride ions, which release electrons at the electrodes for generating electricity. Only a small portion of thermal energy is converted to electrical energy. The requirements of a high temperature heating device and capability of handling high pressure gas increases design complexity including limitations in size and cost. Another example is conventional hydrogen-oxygen fuel cells, where the electrolytes used have a limited mobility for mass transport of positive hydrogen ions (H^{+}) and therefore the generated electrical energy is much less as compared to that ideally available from the electrochemical conversion. Furthermore, in other types of fuel cells such as those using polymer electrolytes, there is a considerable risk of poisoning of electrodes due to the presence of gaseous impurities such as carbon monoxide, hydrogen sulfide, chlorine etc.

[0003] Solid oxide fuel cells use metal oxide ceramic electrolytes in solid state. These electrolytes operate at a temperature as high as about 1000 ^{0} C. This high operating temperature allows transport of oxygen ions, which release electrons at the electrode

for generating electricity. However, the use of fragile ceramic electrolytes, the requirement of structural materials sustainable at high temperature, and the requirement of additional cooling systems limit the reliability of solid oxide fuel cells.

[0004] Therefore, there is a need in the art for fuel cells that efficiently and reliably operate at lower temperatures than current fuel cells.

Summary of Invention

[0005] An embodiment of the present invention provides a fuel cell assembly comprising at least one fuel cell. The fuel cell comprises an anode and a cathode held in a spaced apart relationship by at least one spacer element comprising an electrically insulating material. A proximal end of the spacer element is in contact with the cathode, and a distal end is in contact with the anode. An electrolyte is disposed between, and in contact with the anode and the cathode. The electrolyte comprises a molten salt having a hydride ion conductance number greater than about 0.95 at a fuel cell operating temperature. A fuel gas inlet, adjacent to the cathode, is provided for delivering a fuel gas to the electrolyte. An oxidizing gas inlet, adjacent to the anode, is provided for delivering a oxidizing gas to the electrolyte. An exhaust port is in fluid communication with the anode.

[0006] Another embodiment of the present invention provides a fuel cell assembly comprising at least one fuel cell further comprising an anode and a cathode held in a spaced apart relationship by at least one spacer element. The spacer element comprises an electrically insulating material. A proximal end of the spacer element is in contact with the cathode, and a distal end is in contact with the anode. An electrolyte disposed between, and in contact with, the anode and the cathode comprises at least one molten alkali metal halide selected from the group consisting of lithium chloride and potassium chloride and further comprising lithium hydride. A fuel gas inlet adjacent to the cathode is provided for delivering a fuel gas, comprising hydrogen, to the electrolyte. An oxidizing gas inlet adjacent to the anode is provided for delivering an oxidizing gas, comprising oxygen, to the electrolyte. An exhaust port is in fluid communication with the anode.

[0007]

Still another embodiment of the present invention provides a fuel cell, which

comprises an anode, a cathode in a spaced-apart relationship with the anode, a source of hydride ions in fluid in communication with the cathode, a source of oxygen in fluid communication with the anode, and an electrolyte. The electrolyte comprises a molten salt, the molten salt having a hydride ion conductance number greater than about 0.95 at a fuel cell operating temperature.

[0008] These and other features, aspects and advantages of the present invention will be better understood with reference to the following description, appended claims, and accompanying drawings.

Brief Description of Drawings

[0009] Figure 1 is a cross-sectional view of the fuel cell for converting chemical energy to electricity.

[0010] Figure 2 is a cross- sectional view of the fuel cell showing the mechanism of electricity generation.

[0011] Figure 3 is a typical application of a fuel cell stack in a centralized generation plant.

Detailed Description

[0012] Referring to Figure 1, one embodiment of the present invention is a fuel cell assembly, which is an array or stack comprising at least one fuel cell 10. A fuel cell 10 according to this embodiment comprises an anode 15 and a cathode 16 held in a spaced apart relationship by at least one spacer element 22. A spacer element 22 according to this embodiment comprises an electrically insulating material, such as, but not limited to, alumina, zirconia, boron nitride, silicon nitride, aluminum nitride, and silicate glass. The spacer element 22 further comprises a proximal end in contact with cathode 16 and a distal end in contact with anode 15.

[0013] In one embodiment, at least one of anode 15 and cathode 16 comprises a hydrogen-permeable solid membrane. The property of hydrogen absorption by these materials allows rapid diffusion of, for example, a fuel gas, which is supplied through the fuel gas inlet 18. In particular embodiments, the membrane comprises at least one material selected from the group consisting of palladium, vanadium, beta titanium,

and an alloy comprising palladium and silver. In another embodiment at least one of the anode 15 and the cathode 16 comprises a sintered refractory material, which also allows rapid diffusion of gas through the porous structure. Suitable sintered refractory materials include, but are not necessarily limited to, molybdenum, tungsten, rhenium, and vanadium. In another embodiment, a composite material comprising the sintered refractory material and the solid membrane is used in at least one of the anode 15 and the cathode 16, for facilitating faster diffusion of gas.

[0014] In certain embodiments, the anode 15 and the cathode 16 are tubular in configuration. Tubular configuration helps to maintain uniformity in flow thereby establishing stable density gradient across the fuel cell. This results in stable, time independent current characteristics of the fuel cell. Additionally, tubular configuration maintains structural integrity and soundness over a long span of time and enhances packaging compactness. In other embodiments, the anode 15 and the cathode 16 are planar. Planar geometrical configuration facilitates in improving diffusion rate, which enhances power density. Additionally, planar configurations are readily available because of ease of manufacturing.

[0015] In some embodiments at least one of the anode 15 and the cathode 16 has a thickness in the range from about 50 microns to about 500 microns. In certain embodiments the thickness of the anode 15 and the cathode 16 is in the range from about 50 microns to about 250 microns. Still in accordance with some other embodiments the thickness of the anode 15 and the cathode 16 can be in the range from about 75 microns to about 150 microns. Generally, thickness of the anode 15 and the cathode 16 is designed to be as low as allowable by mechanical design constraints, in order to minimize resistance of the fuel cell 10.

[0016] An electrolyte 17 is disposed between, and in contact with the anode 15 and the cathode 16. The electrolyte 17 comprises a molten salt having a hydride ion conductance number greater than about 0.95 at a fuel cell operating temperature. Using an electrolyte 17 with a hydride ion (H^-) conductance number in this range ensures that the fuel cell will operate with suitable efficiency to be cost-effective. In some embodiments, the fuel cell operating temperature is in the range from about 250 ^{0}C to about 650 ^{0}C, which ensures that certain suitable electrolyte materials are

in molten state and capable of conducting hydride ions at the desired level of efficiency. In certain embodiments, the fuel cell operating temperature of the electrolyte 17 is in the range from about 250 ^{0}C to about 600 ^{0}C. According to particular embodiments of the invention, the fuel cell operating temperature is in the range from about 300 ^{0}C to about 450 ^{0}C.

[0017] In some embodiments, the electrolyte 17 comprises at least one molten alkali halide and at least one molten metal hydride. The present inventors have found that electrolytes of this type have suitably high hydride ion conductance, at fuel cell operating temperatures in the range described above, which are to be used in embodiments of the present invention. In accordance with one embodiment of the invention the alkali halide is selected from the group consisting of lithium chloride, lithium bromide, lithium fluoride, potassium chloride, potassium bromide, potassium fluoride, sodium chloride, sodium bromide, sodium fluoride, and mixtures thereof. Suitable alkali hydrides include, but are not necessarily limited to, lithium hydride, potassium hydride, sodium hydride, and mixtures thereof. According to one embodiment of the invention the molten salt comprises the alkali hydride in the range from about 5 weight percent to about 25 weight percent of the total molten salt mixture. This ensures mobility of hydride ions even at initial start up of the fuel cell. In particular embodiments, the molten salt comprises the alkali hydride in the range from about 10 weight percent to about 20 weight percent of the molten salt mixture.

[0018] A fuel gas inlet 18 adjacent to cathode 16 delivers fuel gas to the electrolyte 17. The fuel gas, in some embodiments, comprises hydrogen; suitable fuel gasses include, but are not limited to, gasses comprising at least one of methane and propane. Those skilled in the art will appreciate that in cases where a hydrocarbon compound, such as methane or propane, is used as the fuel gas, a reformer (not shown) is used to extract hydrogen from the hydrocarbon compound, and the hydrogen is then delivered to the electrolyte 17 through the fuel gas inlet 18. An oxidizing gas inlet 19, adjacent to the anode 15 delivers an oxidizing gas to the electrolyte 17. In some embodiments, the oxidizing gas comprises oxygen, and in particular embodiments, the oxidizing gas comprises air.

[0019]

Referring to Figure 2, the fuel gas diffuses through the cathode 16. The hydrogen

in the fuel gas reacts with free electrons in the electrode according to the reaction 106.

[0020] $H_{2\,(g)} + 2e^{-} \rightarrow 2H^{-}$

[0021] The hydride ions transported across electrolyte 17 diffuse into and across anode 15, whereupon they contact the oxidizing gas and react with this gas to produce and free electrons. Anode 15 serves as a physical barrier to prevent mixing of the oxidizing gas and the reaction product water with electrolyte 17. The free electrons flow from the anode 15 to the cathode 16 when they are connected through an external load 21. The anode reaction 107 is represented in Figure 2 as follows.

[0022] $\frac{1}{2} O_{2\,(g)} + 2H^{-} \rightarrow H_2O + 2e^{-}$

[0023] Overall reaction is represented by

[0024] $H_{2\,(g)} + \frac{1}{2} O_{2\,(g)} \rightarrow H_2O_{(g)}$

[0025] The above reaction is exothermic and hence maintains the operating temperature of the fuel cell at a constant level after initial start up. The water molecules thus formed in the reaction are converted to vapor phase. Unused gases and water vapor are exhausted through an exhaust port 20.

[0026] Another embodiment of the present invention is a fuel cell comprising an anode15 a cathode 16 in a spaced-apart relationship with the anode 15, a source of hydride ions in fluid communication with the cathode 16, a source of oxygen in fluid communication with the anode, and an electrolyte 17 comprising a molten salt, the molten salt having a hydride ion conductance number greater than about 0.95 at a fuel cell operating temperature. The various alternatives described for elements of the fuel cell assembly of the present invention also apply to these fuel cell embodiments. In these embodiments, the source of hydride ions is often a fuel gas, and the source of oxygen is often an oxidizing gas, as described previously.

[0027] The fuel gas and oxidizing gas can be obtained from a variety of sources and therefore this type of fuel cell is suitable for use in various applications. For example, it can be used in a skid mounted mobile reformer unit where hydrocarbons are cracked to produce hydrogen and is therefore suitable to use in electrically powered

vehicle or any other small-scale generation. A typical fuel cell stack for large-scale generation in central power plants is shown in Figure 3. For large-scale generation in central power plant, hydrogen may typically be obtained from coal gas by water gas shift reaction. Hydrogen gas thus produced from a coal reformer gas in a shift converter 201 is fed to a fuel cell stack 200 at the inlet 204.The fuel cell stack 200 contains individual fuel cell units 210. Oxygen or atmospheric air is fed into the inlet 205 of the fuel cell stack 200.The unused oxygen and the water vapor produced in the reaction as explained above are recycled through a condenser 216 and connecting duct 214. The unused hydrogen is recycled from port 207 though a connecting duct 212. The fuel cell can also be used for space power applications where hydrogen and oxygen can be supplied from a cryogenic storage 218.

[0028] While various embodiments are described herein, it will be appreciated from the specification that various combinations of elements, variations, equivalents, or improvements therein may be made by those skilled in the art, and are still within the scope of the invention as defined in the appended claims.